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When the truth isn't too hard to handle: An event-related potential study on the pragmatics of negation

Mante S. Nieuwland^{1,2} and Gina R. Kuperberg^{1,2,3}

¹Department of Psychology, Tufts University, 490 Boston Avenue, Medford, MA 02155, USA

²MGH/MIT/HMS Athinoula A. Martinos Center for Biomedical Imaging, Bldg 149, 13th Street, Charlestown, Massachusetts 02129, USA

³Department of Psychiatry, Massachusetts General Hospital, Bldg 149, 13th Street, Charlestown, MA 02129, USA

Abstract

Our brains rapidly map incoming language onto what we hold to be true. Yet there are claims that such integration and verification processes are delayed in sentences containing negation words like 'not'. However, research studies have often confounded whether a statement is true and whether it is natural thing to say during normal communication. In an event-related potential (ERP) experiment, we aimed to disentangle effects of truth-value and pragmatic licensing on the comprehension of affirmative and negated real-world statements. As in affirmative sentences, false words elicited a larger N400 ERP than true words in pragmatically licensed negated sentences (e.g., "In moderation, drinking red wine isn't *bad/good*..."), whereas true and false words elicited similar responses in unlicensed negated sentences (e.g., "A baby bunny's fur isn't very *hard/soft*..."). These results suggest that negation poses no principled obstacle for readers to immediately relate incoming words to what they hold to be true.

INTRODUCTION

To make sense of everyday language, it is essential for people to map what is said onto what they hold to be true about the world. This verification process is carried out routinely and almost immediately as a message unfolds over time (e.g., Fischler, Childers, Acharyapaopan, & Perry, 1985; Hagoort, Hald, Bastiaansen & Petersson, 2004; see also Singer, 2006), with false statements being more difficult to evaluate than true statements. Yet, a large body of psycholinguistic evidence points to a possible exception: in sentences that convey a negated message, it may actually be harder to evaluate true statements than false statements ("A robin is not a tree/bird"; Fischler, Bloom, Childers, Roucos & Perry, 1983). According to non-incremental, 'two-step' theories of negation, evaluating "A robin is not a tree" is difficult because people suppose the false 'inner proposition' ("A robin is a tree") before applying the negation term to compute truth-value (e.g., Carpenter & Just, 1975; Clark & Clark, 1977; Kintsch, 1974; for review, see Kaup, Lüdtke & Zwaan, 2007; Singer, 2006).

Negation processing has also been studied using Event-Related Potentials (ERPs) (Fischler et al., 1983; Hald, Kutas, Urbach & Pahrhizkari, 2005; Kounios & Holcomb, 1992; Lüdtke, Friedrich, De Filippis & Kaup, in press), which can provide qualitative information about

language processing well in advance of (and without the principled need for) an explicit behavioral response. Those studies have focused on the N400, a negative voltage deflection in the ERP that indexes early semantic processing costs (Kutas & Hillyard, 1980, 1984), be they aspects of semantic retrieval or integration (e.g., Kutas, Van Petten & Kluender, 2006; see also Coulson & Federmeier, in press; Van Berkum, submitted). Although, in affirmative statements, the N400 is modulated by real world knowledge (e.g., Hagoort et al., 2004), previous studies suggest that this is not true of negated statements: in the example above, ‘tree’ elicits a larger N400 than ‘bird’ in both affirmative and negated sentences (e.g., Fischler et al., 1983). In accordance with a two-step account, these results suggest that non-propositional semantic processes precede the decision processes that compute sentence truth-value (e.g., Fischler et al., 1983; Hald et al., 2005; Kounios & Holcomb, 1992; Lüdtke et al., in press).

Although a two-step theory of negation processing can account for much of the data, it seems hard to reconcile with people’s common and almost effortless use of negation in everyday life (e.g., Givon, 1978; Horn, 1989). In fact, the available results might also be explained by taking into account the pragmatics of negation: people normally use negation to reject what plausibly may have been true (for example, earlier statements, exceptions and plausible misconceptions, e.g. “A whale is not a fish”; see Wason, 1965). In contrast, denying something that makes no sense to begin with (e.g., “A robin is not a tree”) violates the default assumptions that people have about speakers communicating rationally and efficiently. Importantly, people expect speaker’s messages to be both true *and* informative (the so-called conversational maxims; Grice, 1975; Sperber & Wilson, 1995). And indeed, difficulties associated with negation are diminished under pragmatic licensing conditions (e.g. Glenberg, Robertson, Jansen, Johnson-Glenberg, 1999; Johnson-Laird & Tridgell, 1972; Wason, 1965). However, such findings are relatively sparse (see Kaup et al., 2007). Moreover, all results concerning the early stages of comprehending real-world statements suggest that negation is not used incrementally (see Lüdtke et al., in press, for review). As pointed out by Kutas et al. (2006), however, ERP researchers have thus far only examined the comprehension of pragmatically unlicensed negation.

In the current ERP study, we attempted to settle this longstanding dispute on the temporal interplay between pragmatic context, negation and world knowledge. We measured ERP responses while participants read statements containing mid-sentence critical words that rendered the statement true or false. In contrast to earlier studies, we did not require ERP participants to explicitly verify the sentences but rather to simply read for comprehension. We contrasted the two-step and pragmatic account of negation by fully crossing negation and truth-value in sentences where negation was either pragmatically licensed or unlicensed. Pragmatic licensing was independently assessed in a naturalness-rating pre-test, see Table 1, which allowed us to separate true-negated sentences into those where the critical word was relatively informative (“With proper equipment, scuba-diving isn’t very *dangerous*”) versus underinformative/trivial (“Bulletproof vests aren’t very *dangerous*”).

According to a two-step theory of negation processing, early semantic processes disregard the negation term. This account therefore predicts a larger N400 for false than for true words in affirmative statements, but a reverse effect in negated statements, regardless of whether negation is pragmatically licensed or unlicensed. According to a pragmatic account, however, negation terms are immediately incorporated during sentence comprehension, and early semantic processes are modulated by how well the resulting meaning maps onto real-world knowledge *as well as* by our pragmatic knowledge of what is an informative versus a trivial thing to say. This account thus predicts a larger N400 for false than for true words in affirmative as well as in pragmatically licensed negation statements, but not necessarily in unlicensed negation statements.

METHODS

Development and Pre-test of Materials

We constructed 320 sentence quadruplets, each with two complementary predicates yielding opposite truth-values in affirmative and negated sentences. Negated sentences were identical to affirmative sentences except for the negation term (e.g., an additional or contracted adverb like “is not”/“isn’t”, or the adverb “never”). Most critical words (CWs) were preceded by adverbs (e.g., ‘very’) or auxiliary verbs (e.g., “wouldn’t be”). At least three words followed the CWs before the sentence ended.

To determine whether sentence fragments (truncated after the CW) were, on average, regarded as true/false and as natural/unnatural, we conducted a rating pre-test. We created eight counterbalanced lists of pseudo-randomized sentences using similar procedures as for the ERP experiment (see below). Thirty Tufts students (mean age = 20.2 years; 8 males) each rated one list. For each sentence, they first decided whether its literal meaning was true (1 = false, 5 = true), and second, whether it constituted a natural thing for somebody to say *and mean* in a real conversation (1 = unnatural, 5 = natural). Participants were made aware that sentences could be literally true but unnatural, and were instructed to rate false sentences as unnatural, and to skip any sentences they were unable to verify.

Based on the truth-value ratings, we excluded quadruplets containing true sentences rated below 3, false sentences rated over 3, or sentences that were skipped by more than 2 participants. Based on the naturalness ratings of the true-negated version, we then selected and categorized the 120 most natural and 120 least natural quadruplets as pragmatically licensed and unlicensed respectively. The pragmatically licensed and unlicensed sentences were similarly rated for truth-value across conditions, but critically differed in the naturalness rating of the true-negated sentences (see Table 1; see www.nmr.mgh.harvard.edu/kuperberglab/materials.htm for additional examples).

For the ERP experiment, we created four counterbalanced lists so that each sentence appeared in only one condition per list, but in all conditions equally often across lists. Within each list, items were pseudorandomly mixed with 120 filler sentences to limit the succession of identical sentence types and to maximize the distance between identical CWs (CWs appeared maximally 3 times per list, but generally at least twice), while matching trial-types on average list position.

ERP Experiment

Participants: 28 right-handed Tufts students (9 males; mean age = 20.7 years) gave written informed consent. All were monolingual English speakers, without neurological or psychiatric disorders.

Procedure: ERP participants silently read sentences, presented word-by-word and centered on a computer monitor, while minimizing eye-movements and blinks. To parallel natural reading times (Legge, Ahn, Klitz & Luebker, 1997), all words were presented using a variable presentation procedure. Word duration in ms was computed as $((\text{number of letters} \times 27) + 187)$, with a 10 letter maximum, and an additional 500 ms for sentence-final words. All inter-word-intervals were 121 ms. Following final words, a blank screen was presented for 1000 ms, followed by either a fixation mark or a green-colored word and subsequent fixation mark. Sixty green words were pseudo-randomly distributed following fillers and experimental sentences. Participants indicated by button-press whether these words were conceptually related to the preceding sentence (30 words required ‘yes’, e.g. ‘flute’ following “Mozart was a musical child prodigy”). This ensured that participants paid attention to sentence content. At the fixation mark, subjects could blink and self-pace on to

the next sentence. Participants were given seven short breaks. Total time-on-task was ~60 minutes.

EEG Recording

The EEG was recorded from 29 standard scalp electrodes (referenced to the left mastoid; 2 additional EOG electrodes), amplified (band-pass filtered at 0.01 Hz–40 Hz) and digitized at 200 Hz. Impedance was kept below 5 kOhm for EEG electrodes. Prior to offline averaging, single-trial waveforms were automatically screened for amplifier blocking and muscle/blink/eye-movement artifacts over 650ms epochs (starting 50ms before CW onset). Four participants were excluded due to excessive artifacts (mean trial loss > 35%). For the remaining 24 participants, average ERPs (normalized by subtraction to a 50 ms pre-stimulus baseline) were computed over artifact-free trials for CWs in all conditions (mean trial loss across conditions 10%, range 8–12%).

RESULTS

CWs elicited larger (more negative) N400s in the pragmatically licensed false-affirmative and false-negated sentences compared to true-affirmative and true-negated sentences, whereas they elicited larger N400s in the unlicensed false-affirmative, false-negated and true-negated sentences compared to the true-affirmative sentences (see Figure 1a). N400 effects in both licensed and unlicensed sentences dissipated well before 500 ms after CW onset, and had a typical posterior distribution. An initial 2(Pragmatics: licensed, unlicensed) \times 2(Truth-value: true, false) \times 2(Negation: affirmative, negated) \times 2(Distribution: anterior, posterior) repeated measures ANOVA using mean amplitude in the 300–450 ms time window revealed an interaction between truth-value and distribution ($F(1,23) = 5.02$, $p_{\text{rep}} = 0.9$, $\eta_p^2 = 0.179$), reflecting larger N400 modulations at posterior electrodes. To gain maximal power, all further tests examined N400 ERP responses (300–450 ms) averaged over all 12 posterior electrodes (Pz, Oz, CP1/2, CP5/6, P3/4, P7/8, O1/2), see Figure 1b for the resulting mean values.

A 2(Pragmatics) \times 2(Truth-value) \times 2(Negation) 3-way repeated measures ANOVA revealed an interaction between pragmatics, truth-value and negation ($F(1,23) = 6.01$, $p_{\text{rep}} = 0.923$, $\eta_p^2 = 0.207$)¹. This interaction effect was parsed by conducting two 2(Truth-value) \times 2(Negation) ANOVAs on the licensed and unlicensed sentences separately. In the licensed sentences, false CWs elicited larger a N400 component than true CWs ($F(1,23) = 16.46$, $p_{\text{rep}} = 0.986$, $\eta_p^2 = 0.417$), but there was no interaction between truth-value and negation ($F(1,23) = .012$, $p_{\text{rep}} = 0.166$, $\eta_p^2 = 0.001$). In the unlicensed sentences, there was no main effect of truth-value ($F(1,23) = 3.20$, $p_{\text{rep}} = 0.832$, $\eta_p^2 = 0.122$), whereas there was an interaction between truth-value and negation ($F(1,23) = 17.16$, $p_{\text{rep}} > 0.9863$, $\eta_p^2 = 0.427$) that arose because false words elicited a larger N400 than true words in affirmative sentences ($F(1,23) = 15.32$, $p_{\text{rep}} = 0.986$, $\eta_p^2 = 0.4$), but not in negated sentences ($F(1,23) = .78$, $p_{\text{rep}} = 0.581$, $\eta_p^2 = 0.033$).

DISCUSSION

We contrasted two competing accounts of negation processing by examining neural activity while participants read affirmative and negated sentences that varied in truth-value and pragmatic licensing. As in affirmative sentences, false words elicited a larger N400 than true words when negation was pragmatically licensed. True words in unlicensed negation

¹There was no 3-way interaction in the adjoining 150–300 ($F(1,23) = .82$, $p_{\text{rep}} = 0.589$, $\eta_p^2 = 0.034$) and 450–600 ms ($F(1,23) = 1.11$, $p_{\text{rep}} = 0.642$, $\eta_p^2 = 0.046$) time windows.

statements, however, elicited similarly increased N400 responses as false words. Our results are at odds with a two-step account of negation processing (e.g., Carpenter & Just, 1975; Fischler et al., 1983; Kintsch, 1974), and instead suggest that negation is incrementally incorporated to construct sentence meaning. Because pragmatically licensed negation had no effect whatsoever on the N400 responses to true and false sentences, our results thus suggest that there are no additional semantic processing costs inherently associated with negation (see also Johnson-Laird & Tridgell, 1972; Wason, 1965).

Our results also suggest that incoming words incur an immediate semantic processing cost, as indexed by the N400 (Kutas & Hillyard, 1980, 1984), that not only depends on how well the resultant sentence meaning corresponds to real-world knowledge (cf. Hagoort et al. 2004), but also on whether this meaning is informative or, instead, trivial. We take the processing costs associated with trivially true utterances as reflecting the processing consequences of a violation of pragmatic communicational principles (e.g., Grice, 1975; Sperber & Wilson, 1995). Following contexts such as “Bulletproof vests aren’t very...”, it is most common to encounter a word that is both true and relatively informative (e.g., ‘comfortable’ or ‘cheap’) instead of something trivially true (e.g., ‘dangerous’ or ‘fluffy’). We therefore interpret our N400 findings as reflecting a close interaction between the evolving message-meaning with both real-world and pragmatic knowledge. This pragmatic knowledge might influence word-by-word integration (e.g., Brown, Hagoort & Kutas, 2000), or might contribute to building up contextually-supported expectancies about what upcoming words are likely to be encountered (e.g. DeLong, Urbach & Kutas, 2005; Federmeier, 2007; Van Berkum, submitted).

Clearly, default pragmatic assumptions that addressees have about speakers communicating rationally and efficiently are sometimes violated in everyday communication without the message failing to get through, e.g. in the case of irony. However, even such ‘acceptable’ violations are generally associated with semantic processing costs (Cornejo et al., 2007; see also Coulson, 2004). Although our pragmatically licensed negation sentences were rated as natural for a speaker to say *and mean* (i.e., ruling out an irony interpretation), some of the unlicensed negation sentences could well have been interpreted as ironic (e.g., “Donald Trump isn’t very poor...”).

Whereas we demonstrated that false words and underinformative true words can incur similar semantic processing costs, earlier studies have reported larger N400 responses to underinformative true words than to false words. Semantic-associative priming differences between critical words were probably larger in earlier studies (e.g., robin-bird/tree; Fischler et al., 1983) than in our study (e.g., bulletproof vests – safe/dangerous), which may partly account for the discrepancy if the initial semantic response in earlier studies was dominated by such ‘low-level’ semantic relationships (see Ledoux, Camblin, Swaab & Gordon, 2006, for review). However, several methodological differences further compromise a more direct comparison, including differences in CW antonymy and sentence position, stimulus presentation rate and repetition, and verification task. Thus, we cannot rule out that negation is indeed processed in two stages under certain circumstances (see Lüdtke et al., 2008), and any account of the observed discrepancies across studies is necessarily tentative.

In sum, our results clearly suggest that negation poses no principled obstacle to incremental, high-level language comprehension. In other words, relating incoming words to our real-world knowledge is not necessarily more difficult in negated than in affirmative sentences, so long as negation is used to convey a pragmatically sound message.

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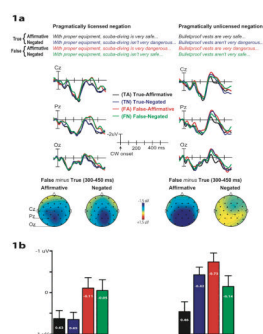


Figure 1.

(a) Grand average ERP waveforms elicited by critical words in all eight conditions at electrode locations Cz, Pz and Oz. Scalp distributions of the relevant mean difference effects in the 300–450 ms analysis window are given below. (b) Mean ERP values (error bars show Mean \pm 1.0 SE) in the 300–450 ms time window averaged over all 12 posterior electrodes.

TABLE 1

Example sentences, and Mean (*M*) and standard deviation (*SD*) of the truth-value and naturalness rating for each condition. Note that ratings were performed on the sentence fragments truncated after the critical word (underlined for expository purpose here only), and that the terms ‘licensed’ and ‘unlicensed’ relate to the naturalness rating for the true-negated sentence version only. The three most right columns provide the average sentence position in words (*Position*), log frequency (*Log-FRQ*; Francis & Kucera, 1976) and number of letters (*Length*) of the critical words.

		Truth-value		Naturalness		Position	CW	
		M (SD)		M (SD)			Log-FRQ	Length
Pragmatically licensed negation								
True-Affirmative	With proper equipment, scuba-diving is very <u>safe</u> and often good fun.	4.47 (0.46)		4.02 (0.54)		7.4	1.45	6.37
True-Negated	With proper equipment, scuba-diving isn't very <u>dangerous</u> and often good fun.	4.52 (0.40)		3.90 (0.44)			1.52	6.32
False-Affirmative	With proper equipment, scuba-diving is very <u>dangerous</u> and often good fun.	1.37 (0.40)		1.38 (0.37)				
False-Negated	With proper equipment, scuba-diving isn't very <u>safe</u> and often good fun.	1.39 (0.38)		1.36 (0.37)				
Pragmatically unlicensed negation								
True-Affirmative	Bulletproof vests are very <u>safe</u> and used worldwide for security.	4.75 (0.31)		4.02 (0.66)		7.0	1.79	5.02
True-Negated	Bulletproof vests aren't very <u>dangerous</u> and used worldwide for security.	4.77 (0.31)		1.93 (0.39)			1.83	4.97
False-Affirmative	Bulletproof vests are very <u>dangerous</u> and used worldwide for security.	1.19 (0.25)		1.13 (0.19)				
False-Negated	Bulletproof vests aren't very <u>safe</u> and used worldwide for security.	1.25 (0.32)		1.26 (0.44)				